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Research in agricultural engineering has shown decided progress during the past year. While the total amount of work as indicated by number of specific investigations has not shown any great increase, there has been a decided improvement in the character of the investigations. A big feature of this has been the inauguration of individual studies of increasingly far-reaching importance, which fact considerably outweighs in significance the matter of mere amount of the work.

According to the records of the Office of Experiment Stations, 317 major projects of research and investigation are now in progress at 40 of the State agricultural experiment stations. Of these, 51 are being supported wholly or in part on the Purnell fund and 5 on the Adams fund. Thirty-six are being conducted in cooperation with the different bureaus of the U. S. Department of Agriculture, including the Bureaus of Public Roads, Agricultural Economics, Plant Industry, and the Forest Service.

The subject of machinery leads with 132 projects at 33 different agricultural experiment stations. Structures is second with 41 projects at 21 stations. There are 33 projects in irrigation at 13 stations, 24 projects in drainage at 12 stations, 32 projects in rural electrification at 18 stations, 21 projects in materials at 12 stations, 13 projects in sanitation at 9 stations, 11 projects in land clearing at 6 stations, and 10 projects in soil erosion at 9 stations.

Machinery

The investigational work in mechanical farm equipment has continued to grow and redevelop in a gradual and very healthy manner. The influence of the activities of the Advisory Council on Research in Mechanical Farm Equipment is still being felt in many quarters. The elimination of superficial and poorly directed investigations and the reorganization of general investigations into specific and fundamentally sound research studies have been going on in a sound and conservative manner.

Harvesters and Threshers.---The 132 projects in the subject include 20 studies of harvesters and threshers at 14 stations. Studies of combines and combining practices especially have assumed considerable importance. These have advanced far enough to show that combining, when properly done, saves considerable power, time, and labor. However, it presents several disadvantages, among the more important being the apparent necessity of providing means of artificially drying the grain, and efforts to correct this difficulty are being made by several of the experiment stations and by the U. S. Department

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of Agriculture. From the standpoint of labor economy the necessity of developing portable drying outfits seems apparent. From the standpoints of design and manufacture basic facts relating to the mechanism and requirements of the removal of moisture from grain are essential. Improper design and adjustment of cylinders and concaves such that the requirements of different kinds and conditions of grain are not adequately met appear also to offer important problems owing to the losses of grain involved. Grain losses back of the cutter bar have been found to be important also in some localities. The windrow-pickup method of handling the cut grain has been found to offer possibilities in several localities, and considerable progress has been made in the development of the bulk handling of the threshed grain. The economical disposal of straw is still an important problem.

The above combining problems call at this stage for studies of the requirements and mechanism of cutting, threshing, handling, and drying of grain. Power as well as grain is being wasted by the use of inefficient methods and equipment, and it is not enough to merely test equipment which is already available. Efforts must be made to determine what actually takes place when grain is properly cut and threshed and the basic requirements therefor, and to what extent and in what specific respects available equipment falls short of adequately performing these operations. It is only with a complete knowledge of the requirements and the specific inadequacies of the equipment that manufacturers can produce the right kind of grain harvesting and threshing machinery.

Similar conditions exist with reference to the development of potato harvesting equipment. Potato harvesters are being studied in this Country and in Europe, and the investigations for some time have been centered on certain power and labor consuming details such as elevating, cleaning, and the like. Interesting results have been obtained at the Pennsylvania Experiment Station and in Germany. In the latter studies considerable time has been devoted not only to elevating the potatoes but to cleaning them. So far no type of sieve cleaner has been fully successful in separating heavy soil from potatoes, although in the lighter sandy soils good results have been obtained with horizontal wheel type sieves. It appears also that proper lubrication of these machines is offering quite a problem, the depreciation in oscillating plane sieve cleaners being especially high for this reason.

Progress is being made also in the efforts to develop corn and cotton harvesting methods and equipment which of necessity are gradually being concentrated on specific features of the equipment. For example, the corn harvesting studies at the South Dakota Experiment Station are dealing primarily with the optimum diameter, length, speed, and angle of husking rolls. These studies, as well as those on grain and potatoes, also call for close cooperation with the field crop specialists concerned. The production of cotton which ripens uniformly, of corn with the ears at the proper height and of uniform height, and of uniformly ripening grain, for example, are important features of the development of power, time, and labor saving methods of harvesting. The research agricultural engineer should give full consideration to the agronomic features of the problem in each case, therefore, in order that the solution to the specific problems of harvesting may occur at the most profitable medium point.

Power Requirements for Mechanical Operations.--The research program at the experiment stations includes 19 studies at 14 stations on the power requirements of different mechanical operations of the farm. Some of these are rather general power surveys, but several relate to the power requirements of specific operations involved in the production or processing of individual crops such as corn, cotton, potatoes, hay, and the like. Such studies, when concerned with specific operations related to definite crops, serve an extremely useful preliminary purpose in showing the distribution of power utilization in the production of a crop, and at what points efforts can be made most profitably to reduce this consumption of power and labor by engineering manipulation.

Tractors and Tractor Economics.--There are 12 projects relating to the engineering development of tractors at 9 experiment stations, and 4 projects relating to tractor economics at 4 experiment stations. The economic studies serve a very useful purpose in pointing to the inadequacies of available tractors for specific cropping operations from the standpoint of cost. The engineering studies which are, for the most part, being conducted in cooperation with field crop specialists are now narrowed down in most cases to the consideration of specific features such as traction, stability, steering, bearing wear and lubrication, carburetion, air cleaning, and the like. The California Experiment Station reported further progress in the development of suitable breakpins for the hitches of tractor drawn implements. The same station also found that the most satisfactory air cleaners for carburetors are the oily filter types. Progress also was reported in the studies of crank case oil filters, it being found, for example, that filtration of the oil reduces engine wear considerably, and that carbon rather than other solid foreign matter in the oil limits the useful life of such filters. The Alabama Experiment Station continued the study of the fundamental factors influencing the traction of wheel tractors, progress of considerable practical utility being made.

As pointed out in a previous paper* it seems that at this stage the research engineer should consider the tractor, not as one big problem, but as a combination of several problems each one of which will be subjected to a definite and limited study based upon a clarified vision of the problem, a sound technique, and a profound knowledge of the specific requirements of the agricultural power operations concerned.

Engine Fuels.--As usual considerable investigational work has been in progress relating to the development of internal combustion engine fuels for specific purposes. Most of this work is in progress in research institutions other than the State agricultural experiment stations, but it is of interest to agricultural engineers since its purpose in general is to reduce detonation and carbon deposition and to produce maximum power from liquid fuels as cheaply as possible. The results have shown that different conditions of carburetion, fuel composition, and gaseous explosion are required for varying conditions of service for optimum performance. Since agriculture utilizes so much power and

*Organization of Research in the Adaptation of the General Purpose Tractor (Agricultural Engineering Vol. 11 (1930), No. 2, pp. 65-68).

[illegible] kinds of hays under controlled conditions of temperature and moisture with the idea of learning something of the physiological mechanism of this process at different periods during growth and curing, and how it may be controlled by artificial means. This should provide a basis for developing the methods and equipment necessary to produce the desired results in terms of cured hay most effectively at least cost. It is planned to supplement the physiological, engineering, and chemical studies with feeding and digestion trials to complete the necessary information relating to basic requirements for drying. Fully controlled studies of this character are what are needed at this time to bring the design, manufacture, and operation of crop drying apparatus down to a rational and economical basis.

Tillage Machinery and Draft of Machinery.--There are 7 projects at 6 experiment stations related to the development of tillage machinery, and 7 projects at 7 experiment stations which deal with the draft of farm machinery, mainly tillage tools, under different conditions. Several European agricultural research institutions are engaged also in studies of a similar nature. In addition to the corn-borer control machinery investigations being conducted by the U. S. Department of Agriculture, at least one experiment station is engaged in a definite study of corn-borer control tillage machinery. Incidentally the U. S. Department of Agriculture also is engaged in a plow draft study in connection with the development of corn borer control tillage methods.

In the majority of instances the studies of tillage tools now relate to rather specific problems. The Alabama Experiment Station is continuing the study of the specific dynamic properties of soil which influence the elements of tillage implement design, and the California Experiment Station is studying the dynamics of the tillage machines themselves. The draft studies, particularly those at the Iowa Experiment Station and those being conducted in the corn-borer control work, are aimed at the reduction of the draft of specific tools to a minimum through engineering manipulation.

The wearing properties of tillage tools are receiving considerable study, there being evidence of the existence of certain relations between wear and friction with the soil. In this connection some success has been attained by plating tillage tools with various materials to reduce the wear, but so far this practice is suggestive rather than indicative as it does not appear to have been definitely associated with the physical principles of friction between soil particles and solutions, and the metal surfaces of tillage tools. In connection with iron and steel corrosion tests in soils the U. S. Bureau of Standards has found a relation to exist between the ability of a soil to react chemically on iron with liberation of hydrogen and its total acidity as indicated by titration. This finding, together with the results of the physical studies at the Alabama and California Experiment Stations suggests that the logical development of tillage tools which will scour properly and give the desired degree of tilth with a minimum of draft must be based primarily upon a knowledge of the physico-chemical relations of soils and soil solutions of different characters and compositions and the metal surfaces of the tools themselves. Simple field tests of a comparative nature are no longer adequate to yield the basic data needed by the designers and manufacturers of tillage tools. The problem must be solved on a sound fundamental basis for different soil types and the results interpreted in terms of tillage tool specifications which the manufacturer can use. Cooperation with soil technologists, field crop specialists and metallurgists seems imperative for success in this work. The number of researches now under way is sufficient evidence that only a thorough solution of the physical and chemical problems involved will meet the requirements of the situation.

Fertilizer and Seeding Machinery.--In addition to the study of fertilizer machinery by the U. S. Department of Agriculture, 6 experiment stations have 7 projects in operation aimed at the development of fertilizer distributing machinery. The Joint Committee consisting of representatives of the National Fertilizer Association, the National Association of Farm Equipment Manufacturers, the American Society of Agricultural Engineers, the U. S. Department of Agriculture, and the State agricultural experiment stations relating to the study of fertilizer distribution has been quite active in

stimulating sound studies in the subject.

The necessity for controlled studies with different soils and crops and different types of fertilizers has become evident. The aid of the laws of physics is being invoked quite freely in this work for the reason that they can no longer be ignored. A recent report emanating from the U. S. Department of Agriculture on factors affecting the drillability of fertilizers emphasizes this point. Proper fertilizer placement for different crops is also important and the study as a whole calls for the close cooperation of engineers, soil technologists, fertilizer chemists, and field crop specialists in order to secure the basic information needed by the designer and manufacturer of fertilizer distributing machinery.

The situation is similar with reference to seeding machinery, there being at least 6 projects active at as many experiment stations in the subject. For example, the problem of cotton planting in soils infected with wilt and other diseases and which form a thick crust after rainfall is leading the investigators into studies of the rupturing strength of soil crusts and the vertical pushing power of individual growing cotton plants in order to secure information as to the requirements of planting to insure a stand of cotton. Simple comparative field tests of planters do not give enough information. Studies made in cooperation with crop specialists and soil technologists are necessary to develop the fundamental requirements of planting for each crop and soil so that the designer and manufacturer of planters can provide the necessary equipment without a great deal of preliminary and expensive "shooting in the dark."

Miscellaneous Machinery.---There are several projects in operation at the experiment stations and elsewhere relating to belt driven machines such as silage cutters, feed grinders, and the like, and in some instances relating to specific features of field machines such as power take-off devices, steering gear, and the like, for tractors. In the majority of these instances the work has now narrowed down to a study of one or two important specific things, the obvious purpose being to deal in a technical manner with individual rather than collective problems.

This sensible procedure is resulting in sure progress which was not always obtained by superficial and general testing methods. The research program in mechanical farm equipment and its needs now seems to be clarified to a considerable extent. It is the obvious primary duty of research agencies to establish the basic requirements for the different farm machines. It is their further duty to determine if available machines in each case meet these basic requirements. If in any case available machines do not meet the basic requirements it is the final duty of the research agencies to establish in what specific respects they are deficient and the basic principles of their proper performance and necessary redevelopment in order to provide designers and manufacturers with the information essential to permit the production of efficient mechanical equipment by modern mass production methods.

Structures

The program of research in farm structures appears to be rather limited in scope. However, if the 13 projects in farm home sanitation and the 21 projects in materials of construction are included under structures, the program at the agricultural experiment stations reaches a total of 75 active projects at 28 experiment stations.

Ventilation of Animal Shelters.--It appears that ventilation of animal shelters is the most important structures problem at the experiment stations at present, there being 14 active projects at 11 stations. These studies deal with the heating and ventilation of poultry houses, dairy and stock barns, and hog houses. Some progress was reported in these studies during the year, especially with reference to the ventilation of poultry houses. The Iowa and Nebraska Experiment Stations, for example, appear to have found no correlation between humidity in poultry houses and winter production of eggs, but that large egg production and general health seem to accompany small temperature fluctuations. The California Experiment Station pointed to the value of roof insulation in controlling temperatures in poultry houses and the New York Cornell Experiment Station showed the value of open front poultry houses with reference to egg production.

The investigation at the Iowa Experiment Station on the air requirements of poultry as a basis for poultry house design while proceeding slowly is still to be considered the type of research undertaking which is really needed. The testing of different types of poultry houses and ventilation systems has been going on for years but has never fully yielded the basic information needed for the design of poultry houses to meet different conditions. A knowledge of the air, moisture, and temperature requirements of different breeds of poultry for maximum production is essential to the proper design of such structures. The securing of this basic data entails controlled studies made in cooperation with poultry specialists, animal pathologists, and biological chemists.

Dairy and Livestock Structures.--There are 6 studies of dairy and livestock structures active at 3 experiment stations. These deal with ventilation and construction and in some instances are cooperative with animal nutrition and biological chemistry departments for the obvious purpose of securing basic data as to the physiological requirements of dairy and other livestock for housing conditions. Such cooperation seems essential to success in the development of such structures.

Crop Storages.--Crop storages are receiving an increasing amount of attention in the experiment stations. It is being recognized that comparative tests of storages which will house several different crops are frequently almost useless for yielding basic data which can be used in design.

The tendency now is to study the storage requirements of individual crops such as potatoes, sweet potatoes, apples, beets, carrots, and the like. This is calling for close cooperation with plant physiologists and has resulted in the rather general finding that, physiologically, crops vary quite widely in their storage requirements. The factor of storage diseases complicates the situation and calls also for cooperation with the plant pathologist.

Interesting and important information has been obtained regarding the influence of different conditions of storage on the prevalence of various storage diseases. Finally it has been found that type of storage may profoundly influence the nutritive quality of stored crops. This, therefore, calls for a measure of cooperation with the nutrition chemist before all the basic requirements for the storage of a particular crop are fully known.

Farm Home Sanitation.---The 13 projects in this subject at the experiment stations deal with sewage disposal, heating and ventilation, and water supply. While considerable has been learned regarding the disposal of sewage from farm homes, there are still several unsolved problems which relate to the tendency toward increased industralization of agriculture. Where farming becomes almost a community proposition the sewage disposal problem assumes the proportions of that of the small town as to size, but is likely to be considerably more complicated on account of the complex nature of the sewage coming from dairies and other processing plants as well as from dwellings.

Water supply problems are always present and call for constant watchfulness. The study of these in connection with sewage disposal problems which are considered as related to soil and topographic conditions seems important, and cooperation with health officials sometimes expedites the work.

Home heating and ventilation has been extensively studied, especially by agencies other than the agricultural experiment stations, such as the State engineering experiment stations and the American Society of Heating and Ventilating Engineers. In this connection much work has been done on radiator design and on minimizing heat losses through proper insulation. Much data is now available from various research agencies relating to heat transfer through different types of construction which may be used in the design of residences, animal shelters, or crop storages.

Materials of Construction.---The investigations of adobe and rammed earth as structural materials have continued at several of the experiment stations. In California the use of sun-dried brick, rammed earth, and poured earth appear to be the practical methods of using earth in the walls of farm buildings. The same general results appear to have been obtained elsewhere.

Investigational work has been continued at several experiment stations on the preservative treatment of fence posts, shingles and other structural features of farm buildings. While most of these are still service tests of long duration, the tendency now is to develop laboratory tests simulating service conditions and to subject treated timbers to them, thus securing results in a relatively short time. This procedure calls for cooperation with forest pathologists, entomologists and biological chemists who are familiar with the natures and activities of the different insects, fungi, and bacterial diseases which attack wooden structural members of farm buildings and fences under various conditions. Such cooperation should provide a relatively exact knowledge of the requirements to be met by preservative treatment of structural timbers and should make available standards by which the degree of effectiveness of preservative treatments can be measured. The American Wood Preservers Association, the American Forestry Association, and the Forest Products

Laboratory of the U. S. Department of Agriculture are also contributing valuable information on this subject and the Forest Products Laboratory is conducting research which has contributed numerous basic principles of design of timber structures.

The existing program of research in farm structures as a whole does not appear to be very profound or comprehensive in scope. Quite evidently the appointment by the Secretary of Agriculture of an Advisory Council on Research in Farm Structures and of a Director thereof to study and clarify the field of research offered was a wise and timely move. The field of farm structures seems bristling with important problems calling for solution, and it appears advisable to identify these, classify them with reference to their agricultural significance and cooperative contacts, and organize and prosecute projects of research where such are justified.

Reclamation

The program of research in land reclamation at the State agricultural experiment stations includes 33 projects in irrigation, 24 in drainage, 11 in land clearing, and 9 in soil erosion, or a total of 77 projects at 24 stations.

Irrigation.--The study of water resources has assumed considerable proportions, there being 10 projects active at 8 experiment stations. The U. S. Geological Survey also has continued to contribute valuable information on a large scale relating to water supplies available for irrigation. The experiment station investigations in the subject deal with both surface and underground waters and seek to establish principles governing their occurrence, amount, and movements. For example, the Utah Experiment Station has learned considerable regarding the manner of occurrence and movement of mountain snow waters which has aided in their conservation and control for irrigation.

Duty of water investigations continue at 4 experiment stations. However, these are no longer the conventional type of duty of water tests but are closely related to the more advanced studies, the purpose of which is to establish the principles governing economical and efficient irrigation practices of which there are 6 at 5 experiment stations. These studies as a rule are cooperative with plant physiology, the purpose being to secure information relating to the basic requirements of different crop plants for water to serve as a standard in the development of economical irrigation practices. They are also cooperative in several cases with soil technology, the purpose being to learn more of the principles governing the existence, movements, and factors of availability of water to crops in various soil types and how these may be controlled, and thus to provide a further basis for the development of economical practices in irrigation water utilization. The Idaho Experiment Station especially has reported progress in this connection and has been able to derive a mathematical expression governing the flow of water in thin sheets in certain soils. Thus duty of water is approached from both the standpoints of how much water a crop plant actually needs and how much can be accomplished with a unit quantity of water in a particular soil. The Arkansas Experiment Station has reported progress in determining the duty of water for rice in the State and the New Mexico, Arizona, and California Experiment Stations have advanced the knowledge of the irrigation of grain,

hay, cotton, fruit, and root crops considerably in this connection.

Drainage.--The drainage investigations at the experiment stations are being narrowed down from the broad general demonstration type of field drainage experiment largely to studies of the principles of soil hydraulics governing the movement of water through soils under the influence of drainage equipment. The purpose is obviously to provide a sound basis for the design of drainage systems for different conditions of soil, crops, and climate. A similar tendency is noted in the drainage investigations in Europe, particularly in Germany and Sweden. Cooperative studies in soil technology and agricultural engineering are gradually yielding the principles of soil hydraulics needed to determine the size, depth, and spacing of drains in different soils, and the relations of these principles to the moisture and soil ventilation needs of different crop plants are being established.

It appears from the experience at research institutions in this country and abroad that permanent progress in the development of economical irrigation and drainage practices depends largely upon the results of research which fully considers the physiological requirements of the crops and the technological requirements of different soils, as well as the hydraulic engineering principles governing the actual mechanical practices of water application to and removal from soil.

Land Clearing.--Land clearing investigations are active at 6 experiment stations. They deal primarily with stone, stump, and brush removal by various means and naturally have strong economic features. Land clearing is at best a costly procedure and the problem at this time seems to be to determine how the many different available clearing methods may be adapted to different local conditions with the least cost. Considerable progress has been made in various localities here and abroad, especially where the investigations have been truly engineering in character, and much data are now available on the lifting and shattering power of different explosives, for example, and on the relative efficiency of several different mechanical clearing devices in terms of the resistance of stumps, roots, stones, and the like, to removal.

Soil Erosion.--While the experiment stations have been interested in investigations of soil erosion for several years, the U. S. Department of Agriculture recently took the lead in this work. A special appropriation has made it possible to set up soil erosion experimental fields in various parts of the country where erosion is a problem. Ten agricultural experiment stations also are engaged in studies of soil erosion, some of this work being in cooperation with the Federal Department.

The experiment station program in soil erosion has developed considerably during recent years. The work now calls for cooperation between engineers, soil technologists and field crop specialists in most instances. The purpose is to study the erosive tendencies of different soil types under different cropping and climatic conditions to learn what are the important factors in erosion and how they may be controlled by artificial means or by the manipulation of natural processes. The conservation of runoff water, particularly in regions where periodic droughts offer a problem, is also an important consideration.

The necessity of studying the factors governing storm run-off and soil erosion under controlled conditions is reflected in the fact that some of the experiment stations are now even carrying features of the work into the laboratory in order to isolate soil factors responsible for these losses. Controlled erosion plats of different soil types with varying slopes and crop covers and equipped with catch basins to catch the eroded soil and runoff water have already yielded important information. Laboratory studies have added further to this information so that a grist of basic facts is now becoming available for use in the design of runoff and erosion prevention measures.

On the whole, land reclamation, including irrigation, drainage, land clearing, and soil erosion and storm runoff prevention is one of the oldest branches of agricultural engineering from the standpoint of research and investigation. In a way, however, it is still in its infancy and is bristling with problems of engineering hydraulics, soil technology and dynamics, and engineering mechanics which need fundamental solution. The tendency now is in that direction and it seems desirable that agricultural engineers interested in the fundamental development of land reclamation practices plan to direct their energies toward the permane solution of some of the important specific problems involved.

Rural Electrification

The 32 projects in rural electrification at the agricultural experiment stations are rather widely distributed among 17 stations. The investigational work in the subject has been rather slow in getting a foothold in the experiment stations largely for the reason that up until recently a considerable proportion of that active has been financed and conducted by State committees working in conjunction with the National Committee on the Relation of Electricity to Agriculture. Another reason was the fact that when the movement started there was a wealth of information which was susceptible of immediate practical application, and such problems as were encountered were largely of a practical rather than a fundamental character.

However, the Committee on the Relation of Electricity to Agriculture has been one of the first agencies to recognize the fact that the initial supply of practical information relating to the use of electricity in agricultural practices, while relatively large, is limited and not sufficient to bring about general rural electrification. That Committee pointed out the necessity of ultimately developing enough new uses of electricity in farming to make rural electrification wholly worth while for all concerned.

It is in this connection that the experiment station program in rural electrification has undergone a gradual but comprehensive development. While the program in the subject itself numbers only 32 projects, a recent study of the programs of agricultural research at the experiment stations revealed a large number of instances in which electricity is or may be made to play an important part in the development of agricultural practices. This feature has been covered in a recent report of the Director of Research of the Committee on the Relation of Electricity to Agriculture and will not be repeated here.

Suffice to say, however, that in almost every branch of agriculture opportunities are offered for new uses of electricity. Each instance of this character

calls for individual fundamental study in cooperation with the agricultural specialists concerned. Crop and dairy products processing, disease and insect control, animal nutrition, and like practices offer opportunities to profitably build up the rural electric load in addition to numerous direct mechanical applications. It seems important that each individual problem be identified and separated for specific study and that it not be forgotten that the designers and manufacturers of equipment must have information relating to basic facts and requirements.

Conclusion

The above discussion suggests that research in agricultural engineering, while not yet of startling proportions or quality, is assuming an air of stability and experiencing a gradual healthy growth which speaks well for those engaged in the promotion and prosecution of this work. The importance of preliminary clarification of a field of research is evident in agricultural engineering, especially where it leads to the identification of important lines of inquiry and stimulates the fundamental study of the individual problems involved. The necessity for cooperation with the agricultural sciences concerned and with other collateral sciences is also emphasized, and finally the entire discussion points to the fact that a highly trained research personnel is essential to the success of the work. The importance of being fully prepared to immediately undertake research in agricultural engineering in case facilities therefor become available cannot be overestimated at this time.